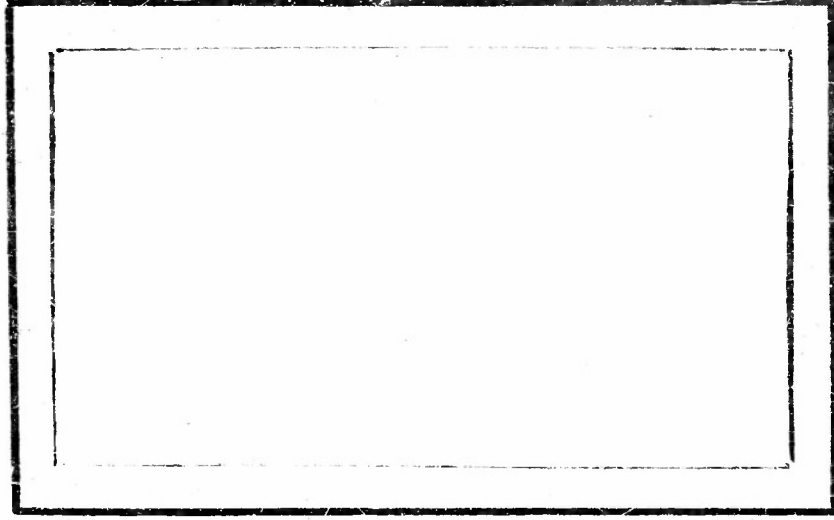


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A Note on the Circulation in the  
Region Northeast of the  
Bahama Islands


by

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Technical Report  
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Director

A Note on the Circulation in the Region  
Northeast of the Bahama Islands

The analysis of 94 drift bottles, launched in the general area in which the Antilles Current is said to flow, together with a study of the dynamic topography of the region, would seem to shed some new light on the nature of the circulation northeast of the Bahama Islands.

As the treatment of these data yields results in sharp contrast to the usually accepted picture of the surface water movement in this locality, a brief history of the concept of the Antilles Current may be appropriate here. Early charts by Kircher (1678) and by Franklin (1786) may be dismissed as being largely imaginative. It was not until the middle of the 19th century that more accurate information became available in the form of temperature measurements made by the U. S. Coast and Geodetic Survey. In the 1848 Report of the Superintendent is a description of what was termed a "double Gulf Stream", an easterly and parallel branch to the main stream.

This report led to the following hypothesis made in 1853 by A. G. Findlay:

"Of the origin of this bifurcation, the following suggestion is offered. That portion of the Equatorial Current which enters the Caribbean Sea passes out through the Straits of Florida, in the well-known current; but that portion, embracing an extent of eight to nine degrees of latitude to the northward of this, would pass northward of Porto Rico, strike the Bahamas, and, being thence deflected northwards, will run parallel to the main stream, and thus cause the double stream in question."

This surmise introduced the idea that there ought to be a clearly defined Antilles Current.

Observations made by Bartlett and Pillsbury followed in the 1880's, but more attention was given to the Gulf Stream than to its possible tributaries. Pillsbury, however, does say that "the course of currents between the Bahama Islands and Cape Hatteras indicates that the Gulf Stream receives large additions from the Atlantic flow."

It was not until 1924 that Wüst seriously presented a case for the Antilles Current, though this was an adjunct to his main study of the Gulf Stream. It is this work which would seem to have established the Antilles Current once and for all, but an examination of his data shows that his results are open to question.

Wüst had but one temperature-salinity section to work with, that made by the USCGS BACHE in February and March of 1914.

This section, running roughly along the 28th parallel, extends no further east than  $76^{\circ}18'$  west longitude. From these data he derived an Antilles transport of  $12.0 \times 10^6 \text{ m}^3/\text{sec.}$  with a velocity at the surface of 35 cm/sec.

Since the time of Wüst's calculations additional data have been collected which better cover this area, and in consequence it is felt that a more comprehensive picture of the circulation can now be derived.

As the present study had its genesis in the consideration of drift bottles launched in this region, these data will be treated first.

There is available a total of 94 recorded recoveries of drift bottles which were launched in a triangular area roughly bounded by the seaward edge of the Bahama group, the 68th meridian and the 30th parallel. These are considered in two groups: 1. Bottles which stranded in the Bahamas or on the eastern coast of the United States; 2. Bottles which somewhere entered the Florida Current and eventually reached foreign shores.

In treating the first group (Figs. 1 and 2) a straight line was drawn from the release position to the recovery point for each bottle and the number of days adrift indicated. To avoid confusion two plots were made, dividing the bottles roughly between summer and winter releases.

There are 63 bottles, 67% of the total, in this group. Of these, 48 bottles were found in the islands, indicating a net southwesterly drift. The remaining 15 bottles which reached the United States are assumed to have followed a similar course at the outset, to have sifted through the islands, and to have entered the Florida Current somewhere near the Straits of Florida. It would seem unlikely that they could have successfully taken the more direct course straight across the Florida Current.

There is no way of determining the initial direction of drift of the 31 bottles which eventually crossed the ocean. As they comprise less than a third of the total, it might be reasoned that they, too, started to the southwest, drifted through the Bahamas and entered the Florida Current near the Straits of Florida.

A plot of the starting positions of these two groups of bottles gives an interesting distribution (Fig. 3). Between  $71^{\circ}$  and  $72^{\circ}$  west longitude there is a region extending 300 miles to the north of the islands from which all bottles traveled southwest, a course approximately normal to the supposed axis of the Antilles Current. Further to the west is a second region of similar nature. As it was here that the BACHE stations were made, the axis of the Antilles Current as determined by Wüst has

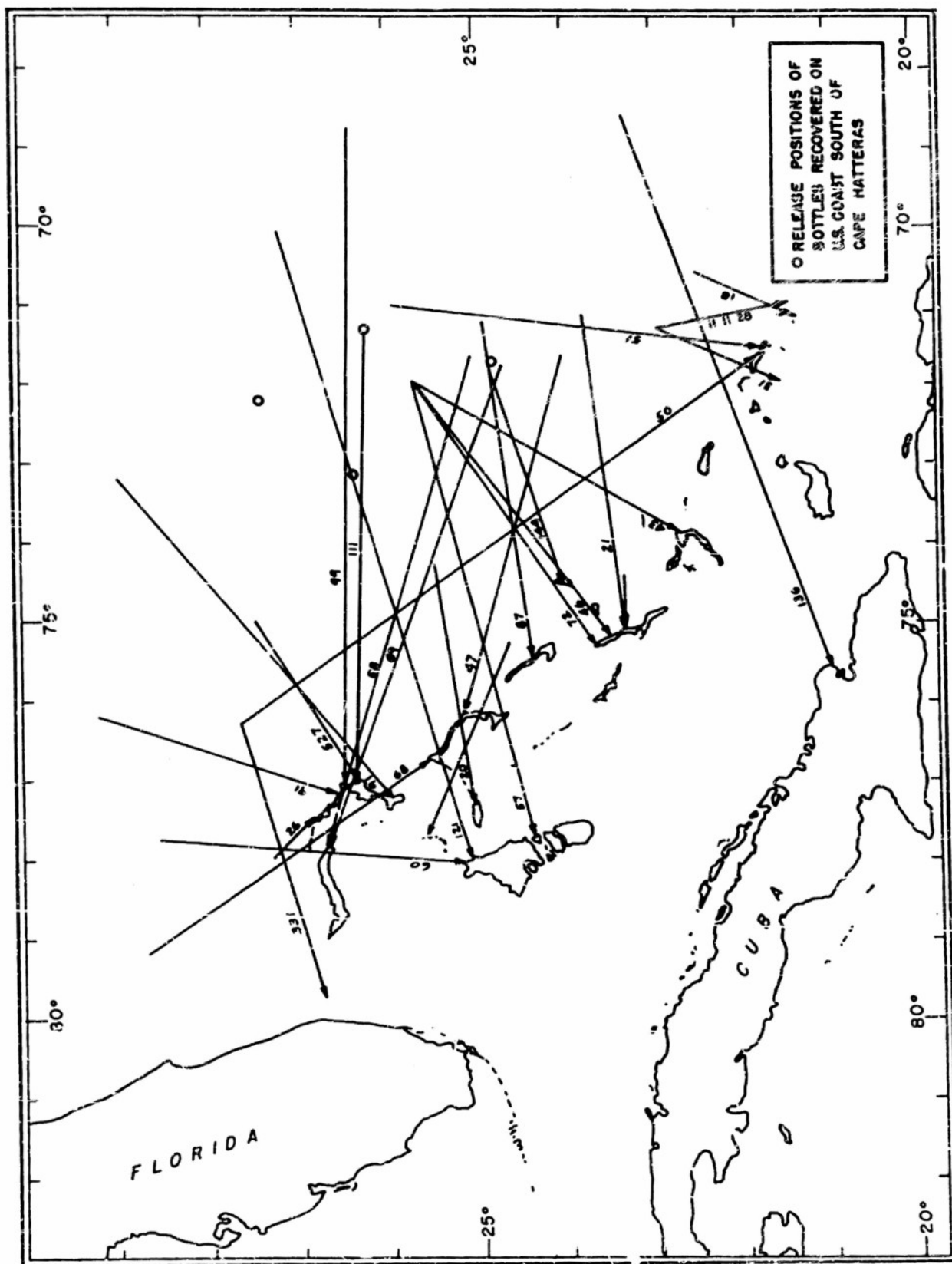


FIG. 1 NOV - APR DRIFT BOTTLE RELEASES

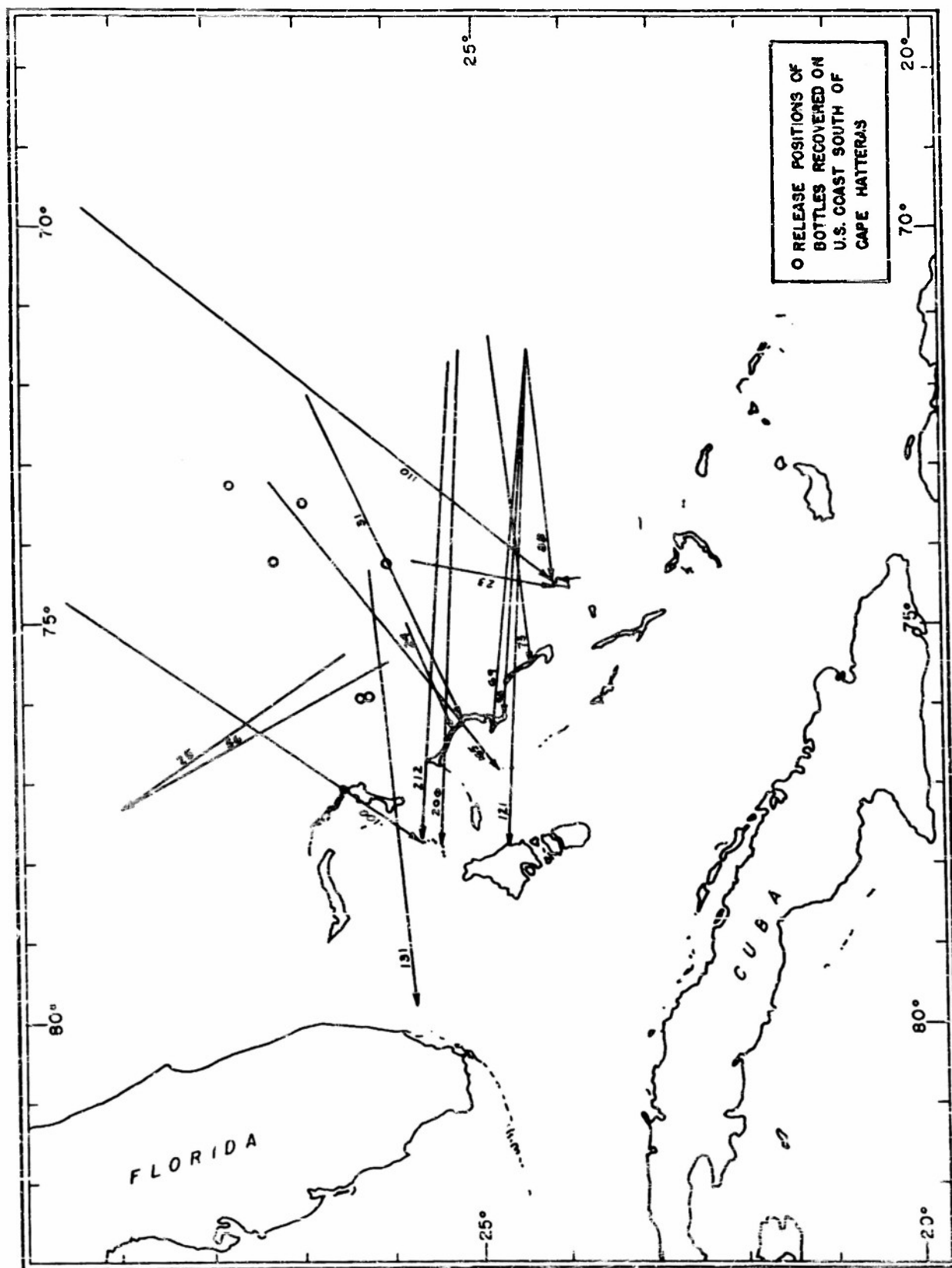


FIG. 2 MAY - OCT DRIFT BOTTLE RELEASES

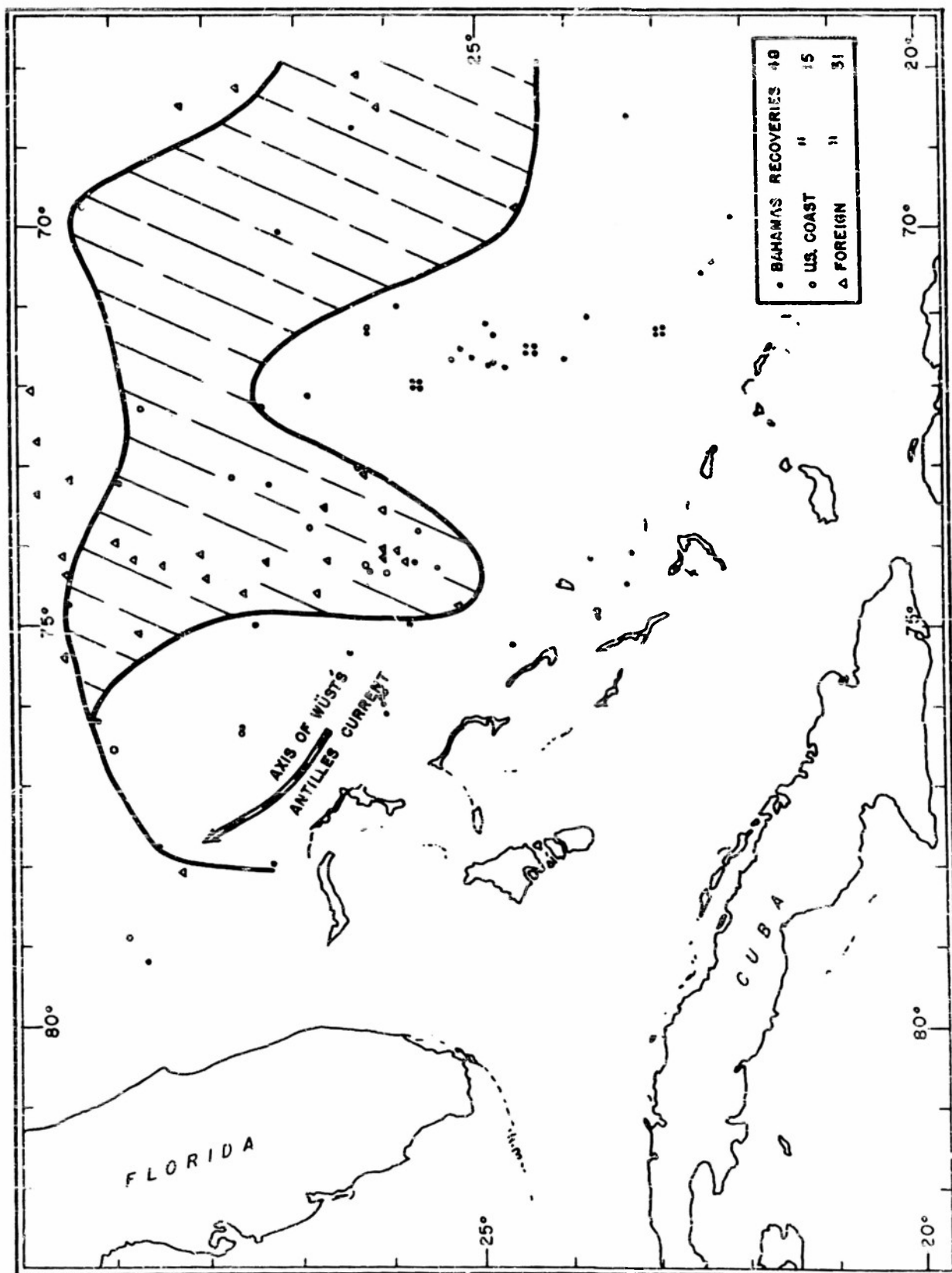


FIG. 3 RELEASE POSITIONS OF ALL BOTTLES STUDIED

been indicated by a dashed arrow for purposes of comparison. From the hatched area bottles eventually stranded either locally or on foreign shores (16 local and 21 foreign). This would appear to be an area of weak and shifting surface currents of no clearly defined character. These drift bottle data, composed of releases made over a period of more than 50 years, clearly give no support to the concept of a surface Antilles Current.

The average monthly current charts published by the Hydrographic Office consistently show a northwesterly set to the currents seaward of the Bahama Islands. It is not clear why these charts give such a different picture from the one which emerges from the drift bottle data. It might be argued that the bottles were subject to the influence of winds, were it not for the fact that they tended to travel well to the left of the prevailing seasonal winds as given on the Hydrographic Office Pilot Charts. Had they moved with a wind-driven surface layer, they should, according to Ekman's theory, have traveled to the right of the winds.

In an effort to estimate the extent to which bottles could have been wind-driven, one example has been chosen for closer study. This bottle was thrown overboard on the 24th of January, 1907, at  $27^{\circ}40'N$  and  $76^{\circ}18'W$ , about 80 miles northeast of Great Abaco Island. It was recovered 50 days later at  $21^{\circ}32'N$  and  $71^{\circ}28'W$ , in the Caicos Islands. The minimum straight line distance it had to cover is 450 miles, at an average rate of 9 miles per day.

This particular bottle was chosen for several reasons. First, it appears to have followed a course directly counter to the Antilles Current thought to exist here; its short period of drift indicates that it could not have deviated to any significant degree from the direct route. The alternative route of a clockwise course through the Sargasso Sea is most unlikely in view of the unreasonable drift rate that would be required. Second, as it is conceivable that unusual winds could have accounted for this particular drift, it seemed a logical choice for closer study.

A day by day analysis of wind force and direction was made for the 50 day period during which the bottle was afloat, using the synoptic weather maps of the U. S. weather Bureau. The results have been plotted as vectors, using Beaufort values, and the straight line direction of drift of the bottle indicated by a dashed arrow (Fig. 4). It is apparent that the bottle itself could not have been wind-driven, nor could it have followed a wind-driven surface current set up during its time afloat. The bottle obviously traveled with a pronounced southeasterly current.



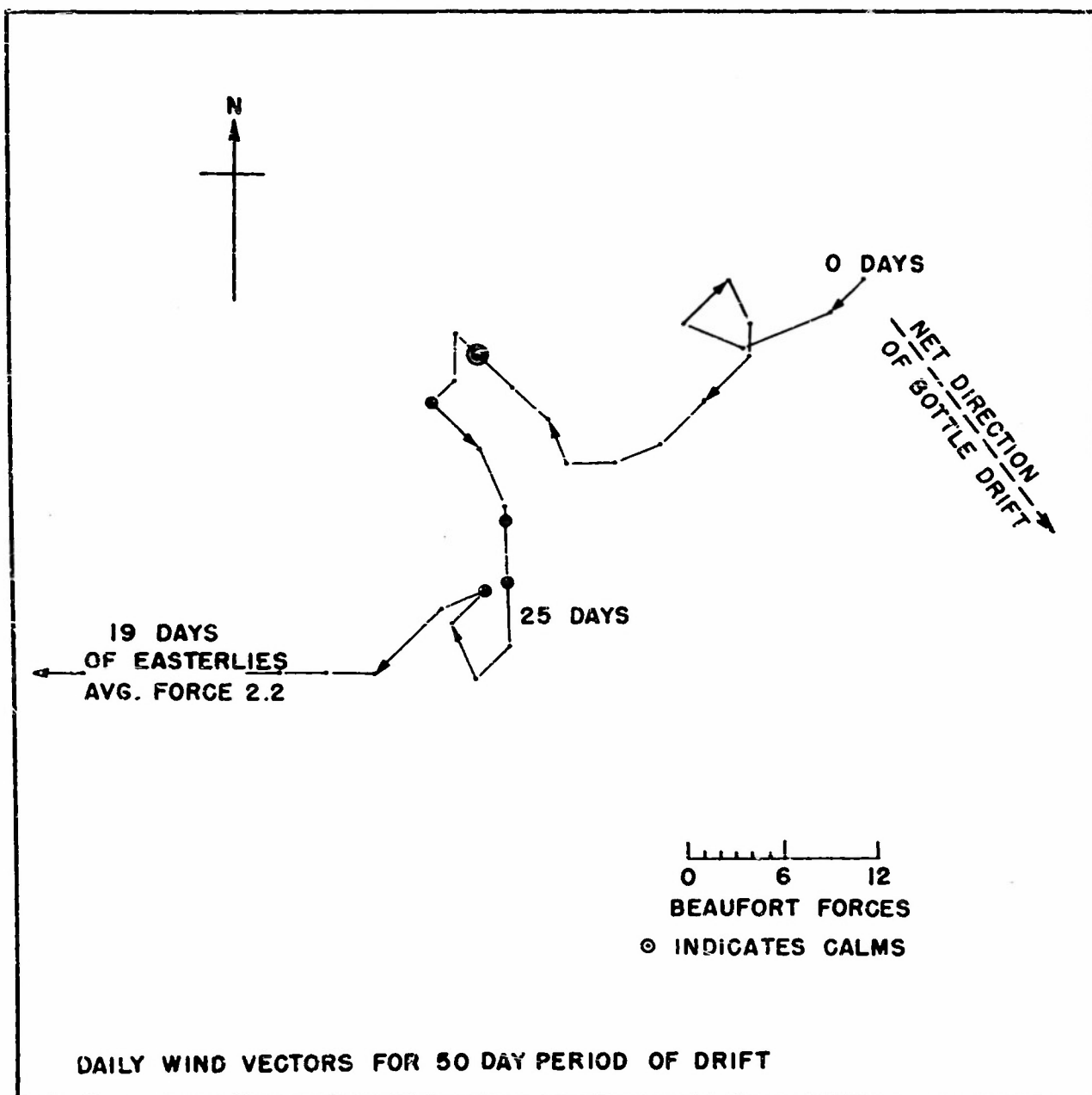


FIGURE 4

In February, 1933, ATLANTIS made a section composed of 14 stations (1464-1477) between Bermuda and Elbo Cay in the northern Bahamas. The dynamic heights at these stations, computed from 2000 meters to the surface, indicate a fairly level topography. The greatest velocities are found at the surface and at 100 meters at approximately 40 miles east-northeast of Great Abaco Island, where values of 28.1 cm/sec were obtained between stations 1475 and 1476. This transport is towards the northwest. Between stations 1474 and 1475 a very weak countercurrent appears extending from the surface to 200 meters with a maximum velocity of 2.7 cm/sec.

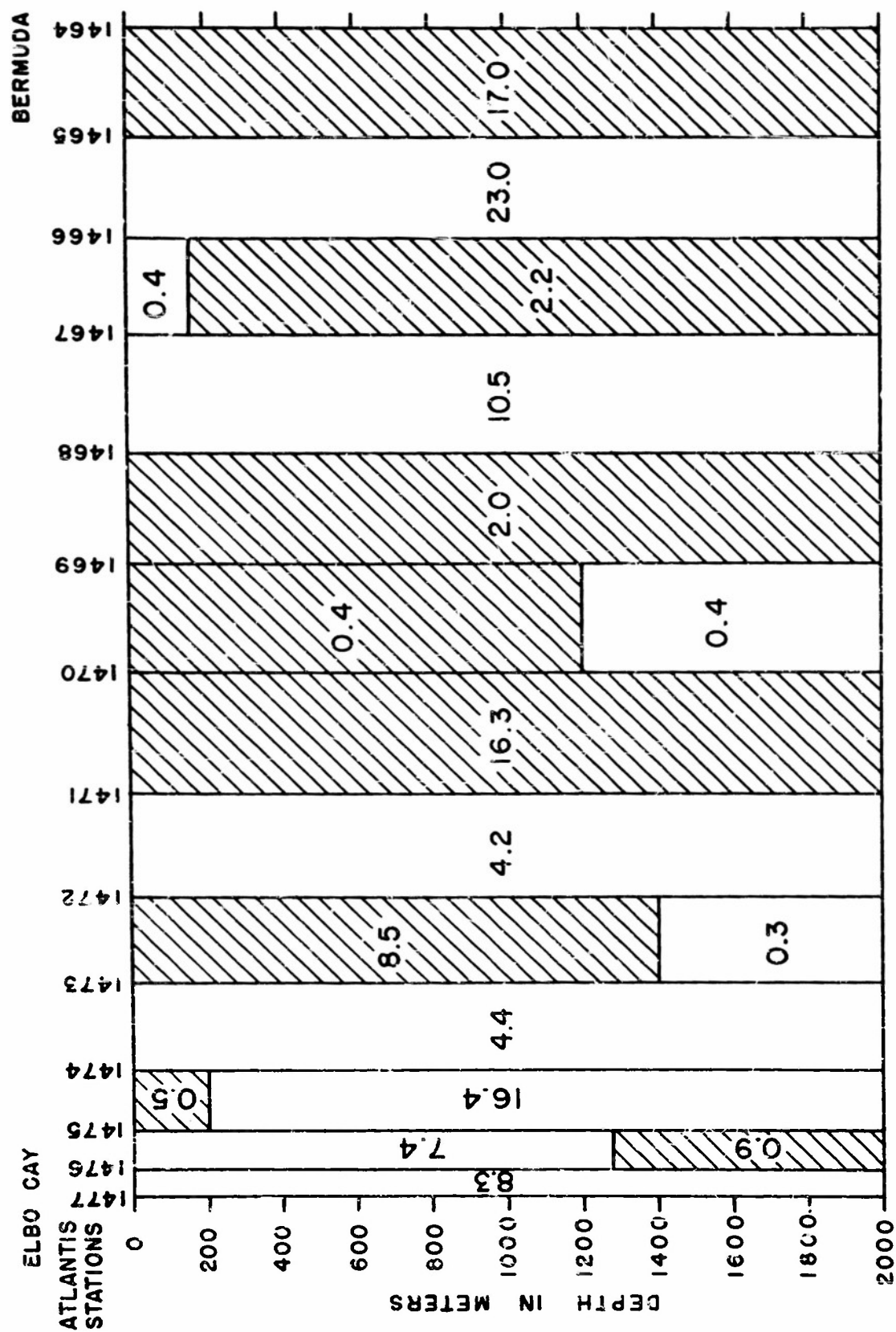
A profile of the computed transport across this section (Fig. 5) reveals no clear-cut pattern. In general, there is a dominant northwesterly flow between the Bahamas and station 1473 approximately 140 miles to the northeast. This may be said to be the Antilles Current as it existed at the time. In this area the net transport to the northwest amounts to  $20.3 \times 10^6 \text{ m}^3/\text{sec}$ . In the center of the section between stations 1468 and 1471 there is a net transport of  $16.5 \times 10^6 \text{ m}^3/\text{sec}$  to the southeast. In the northernmost 1/3 of this section the westerly flow again predominates with a net transport of  $14.7 \times 10^6 \text{ m}^3/\text{sec}$  between stations 1464 and 1468. This portion of the section, extending 285 miles southwest of Bermuda, reveals the most confused pattern, and indicates the existence of either two pairs of countercurrents or two distinct anticyclonic eddies.

Across the entire section there is a net transport of  $12.7 \times 10^6 \text{ m}^3/\text{sec}$  to the northwest. These results fail to account for the estimated  $50.0 \times 10^6 \text{ m}^3/\text{sec}$  increment received by the Gulf Stream between the Straits of Florida and the area off Cape Hatteras.

In April 1947, ATLANTIS made 29 deep stations in the region to the northeast of the Bahama Islands. The dynamic heights of these stations (4532-4561), computed from 2000 meter depths, again show small anomalies and a fairly level topography (Fig. 6). The positioning of these stations in a grid-like pattern affords a better opportunity to study the circulation of the region than does the above section.

At the surface there is no Antilles Current apparent. North of Great Abaco Island there is a cyclonic eddy which attains a velocity of 26.3 cm/sec. South of this there is a general southwesterly flow in the direction of northeast Providence Channel. Further to the southeast are two gentle eddies immediately seaward of the islands, beyond which there is a southeasterly flow.

Stations 4535, 4548, and 4560 (Fig. 6) were selected for a study of transport. Between station 4548 near Turks Island Passage and station 4560, about 375 miles to the north, there



TRANSPORT  $\times 10^6 \text{ M}^3 / \text{SEC}$

FIGURE 5

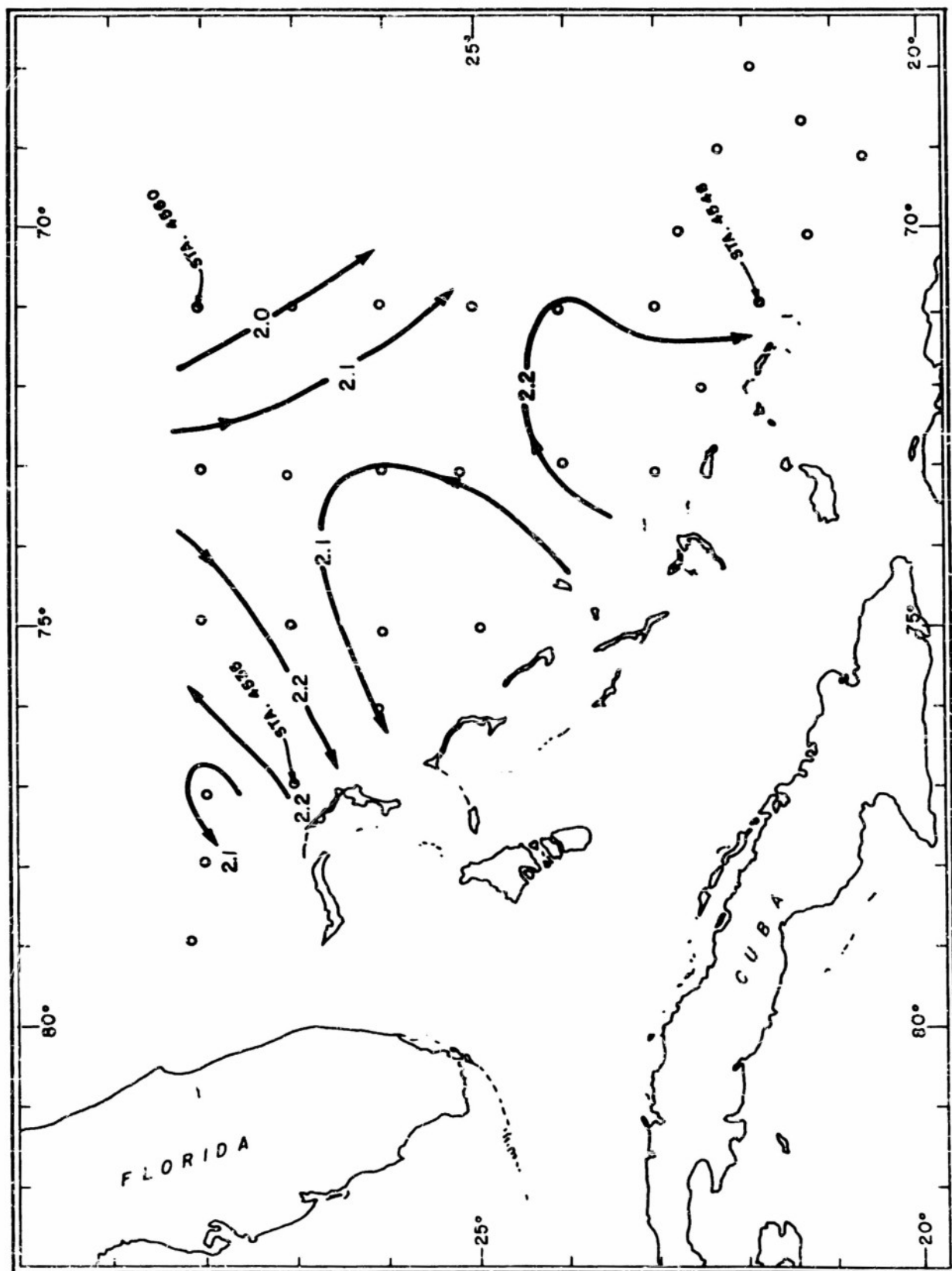


FIG. 6 DYNAMIC HEIGHT ANOMALIES - ATLANTIS, APRIL 1947

is a southeasterly flow confined to the upper 250 meters which amounts to  $2.8 \times 10^6 \text{ m}^3/\text{sec}$ . The greatest velocity found is only 4.4 cm/sec at the surface. Below 300 meters there is a barely perceptible northwesterly movement of water at 0.2 cm/sec, which to the 1000 meter level accounts for a transport of only  $0.7 \times 10^6 \text{ m}^3/\text{sec}$ . The net transport between these stations is  $2.1 \times 10^6 \text{ m}^3/\text{sec}$  to the southeast.

Between station 4535 off Great Abaco Island and station 4560, there is again a slow southeasterly movement in the upper 150 meters. This amounts to  $3.4 \times 10^6 \text{ m}^3/\text{sec}$  with the greatest velocity being 6.5 cm/sec at the surface. Between 200 and 1000 meters there is a slow northwesterly movement with a transport of  $3.0 \times 10^6 \text{ m}^3/\text{sec}$ . This may be said to constitute the Antilles Current as it existed at this time.

The levels between stations 4535 and 4548 show a slow southwesterly movement toward the islands in the upper 150 meters. The maximum velocity is 1.4 cm/sec at the surface; the transport in this layer amounts to only  $0.9 \times 10^6 \text{ m}^3/\text{sec}$ . Between 150 and 1000 meters, however, there is a northeasterly movement of water, probably coming through the various passages between the islands. This amounts to  $2.4 \times 10^6 \text{ m}^3/\text{sec}$  and accounts for the difference in transport below 200 meters between the other two sides of the triangle.

These stations reveal that at the time they were made, no Antilles Current existed in the upper 150 meters. There is a remarkably good agreement between the surface movement derived from these stations and that which has been deduced from the drift bottle data above.

It may be said that an Antilles Current of sorts exists below 200 meters. This current at the time was weak, its maximum velocity being 1.0 cm/sec at 400 meters; its transport of  $3.0 \times 10^6 \text{ m}^3/\text{sec}$  was overbalanced by a flow in the opposite direction of  $3.4 \times 10^6 \text{ m}^3/\text{sec}$  in the surface layer.

The results here are also in agreement with the findings of Defant (The Oceans, p. 684) whose calculations also showed a southeasterly movement of water past the northern edge of the islands.

The conclusion that must be reached from these data are that the surface waters in the region tend to move with a pronounced southerly component of direction rather than to the northwest; and that the Antilles Current appears at depth, varies markedly in its transport from one time to another, and should not be considered a permanent, clearly defined tributary to the Gulf Stream current.

If these conclusions are accepted it must further be inferred that the monthly current charts compiled from navigational records are in error for this region. The set experienced by vessels here must be the result of leeway caused by the moderate though steady easterlies found here.

#### Acknowledgments

The writer is indebted to the Hydrographic Office for making available the drift bottle data above, to Mr. Dean F. Bumpus for his helpful guidance and to Mr. Joseph Chase for his assistance in the determination of wind vectors.

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